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IMPROVED CONFIDENCE INTERVALS FOR THE RATIO
OF THE VARIANCES AND STANDARD DEVIATIONS
FROM TWO NORMAL POPULATIONS

Jeffrey Warren Clouse



NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

Improved Confidence Intervals for the Ratio of the Variances and Standard Deviations from Two Normal Populations

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Jeffrey Warren Clouse

December 1978

Thesis Advisor:

Robert R. Read

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Shortest confidence intervals for the ratio of two variances of normal populations are found as superior alternatives to the widely used equal tail confidence intervals. Extensive tables of high precision are presented which enable the user to easily construct shortest confidence intervals for the ratio of two variances, the ratio of two standard deviations and the shortest unbiased confidence interval for the ratio of two variances.



Characteristics and improved performance of the alternative confidence intervals are discussed in detail and illustrated graphically, with an emphasis on the optimal distribution of complementary tail area between the upper and lower tails.



Improved Confidence Intervals for the Ratio of the Variances and Standard Deviations from Two Normal Populations

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Jeffrey Warren Clouse Captain, United States Army B.S., Ohio State University, 1972

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ABSTRACT

Shortest confidence intervals for the ratio of two variances of normal populations are found as superior alternatives to the videly used equal tail confidence intervals. Extensive tables of high precision are presented which enable the user to easily construct shortest confidence intervals for the ratio of two variances, the ratio of two standard deviations and the shortest unbiased confidence interval for the ratio of two variances. Characteristics and improved performance of the alternative confidence intervals are discussed in detail and illustrated graphically, with an emphasis on the optimal distribution of complementary tail area between the upper and lower tails.



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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to provide tables to facilitate the construction of optimal confidence intervals for the ratio of the variances of random samples drawn from two independent normal populations. This thesis also discusses the characteristics of these intervals. The discussion is restricted to the classes of confidence intervals which are computed from the sums of the squared deviations of the observations from their means.

Scheffé [2] studied analytic properties of this question in 1942. This thesis is an application-oriented extension of his work.

B. BACKGROUND

The classical method of constructing confidence intervals for the ratio of two variances from normal populations consists of splitting the tails of the appropriate F distribution evenly.

One might conjecture that this method has survived through time because of the availability of published F distribution tables, the simplicity of its computation and its resemblance to other evenly split tail schemes. Indeed, when the degrees of freedom of the F distribution are sufficiently large, the classical method yields adequate results for most applications. When the degrees of freedom are small, however, this method results in confidence intervals which are much larger than is necessary.



This thesis describes three classes of confidence intervals which are shorter than the classical ones. Characteristics associated with the shortest intervals are examined in detail and illustrated graphically.

C. IMPROVED CONFIDENCE INTERVALS

Three notions of optimality are treated herein; minimum length for the ratio of variances, minimum length for the ratio of standard deviations and shortest unbiased confidence intervals which Scheffe has shown to be the same criterion as the minimum of the logarithm of the ratio of the variances. These choices are natural, but arbitrary. Other choices could be made also. It is reasonable to assume, however, that the practitioner will prefer a shorter interval to a longer one, and that he will prefer an unbiased one. This thesis concerns itself with finding and recording values with which these classes of optimal confidence intervals can be constructed.

D. CONTENTS OF THESIS

This thesis is divided into four sections. Section I is the introduction. Section II contains the discussion of the statistical statement of the problem and the mathematical solution to it. Section III discusses the accuracy of the tabled values found in Appendix A. These values are the solutions to the optimal length confidence interval problem. Section IV contains conclusions on properties of these intervals along with guidelines for practitioners in applying them.



There are also three appendices. Appendix A contains the tabled values which can be used to construct the shortest length confidence intervals. Appendix B contains graphs of situations illustrating various properties of the criteria chosen. Finally, Appendix C contains the algorithm and the mathematical derivations used in computing the optimal values tabled in Appendix A.



II. DISCUSSION OF LOGIC AND METHODOLOGY

A. MINIMUM LENGTH CONFIDENCE INTERVALS FOR THE RATIO OF TWO VARIANCES AND TWO STANDARD DEVIATIONS

Assume that $\{X_1, X_2, \ldots, X_{M+1}\}$ and $\{Y_1, Y_2, \ldots, Y_{N+1}\}$ are two independent random samples from normal populations. The number of observations in each sample is M+1 and N+1 respectively.

Let γ be an arbitrary level of confidence. It is bounded below by 0 and above by 1. $S_{\chi\chi}$ and $S_{\chi\gamma}$ are defined as

$$S_{XX} = \sum_{1}^{M+1} (X_{i} - \overline{X})^{2}$$

$$S_{YY} = \sum_{j=1}^{N+1} (Y_{j} - \overline{Y})^{2}$$

where

are the sample means. Let

$$s_x^2 = \frac{S_{XX}}{M}$$
 and $s_y^2 = \frac{S_{YY}}{N}$

Under these assumptions, it is well known that the statistic



$$\frac{s_x^2}{\sigma_x^2} / \frac{s_y^2}{\sigma_y^2}$$

is an 'F' random variable with M and N degrees of freedom. 1

To construct a confidence interval for σ_y^2/σ_x^2 , two numbers C1 and C2 are chosen such that

$$\int_{C1}^{C2} h_{M,N}(x) dx = \gamma$$

where $h_{M,N}(x)$ is the F probability density function. Once these values are selected, they are substituted into the probability statement

$$P(C1 \le \frac{s_x^2}{\sigma_x^2} / \frac{s_y^2}{\sigma_y^2} \le C2) = \gamma$$

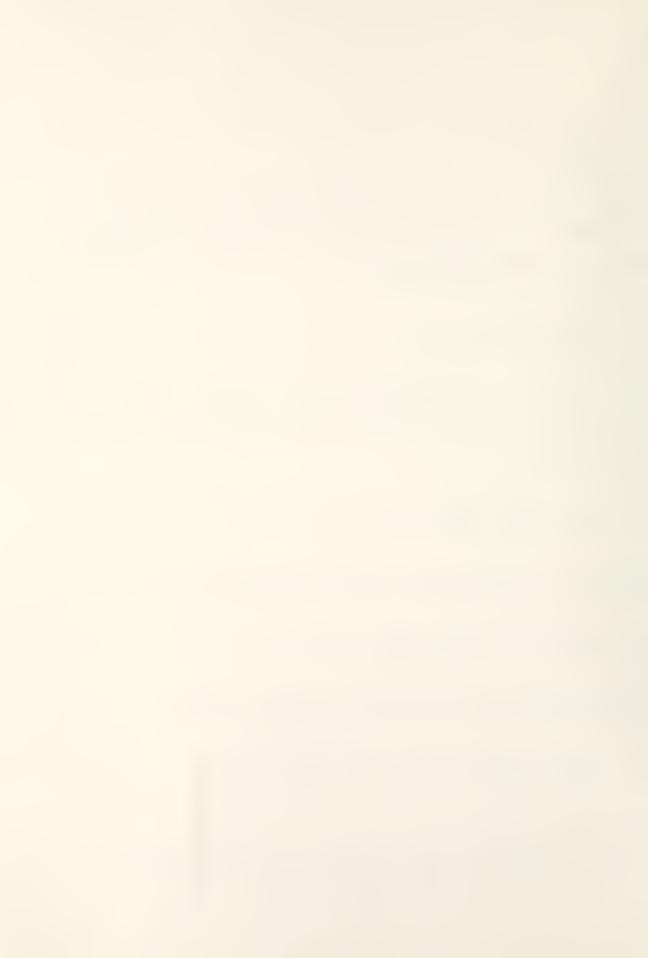
Manipulating through algebra within the parenthesis, one obtains

$$P(\frac{\frac{s^{2}}{y}}{\frac{s^{2}}{x}} \cdot C1 \leq \frac{\sigma^{2}}{\sigma^{2}} \leq \frac{\frac{s^{2}}{y}}{\frac{s^{2}}{x}} \cdot C2) = \gamma$$

This expression yields the desired confidence interval

$$(\frac{s_y^2}{s_x^2}C1, \frac{s_y^2}{s_x^2}C2)$$
 with length $\frac{s_y^2}{s_x^2}(C2 - C1)$.

 $^{^{}l}$ If the population means are known and are used in $S_{\chi\chi}$ and $S_{\chi\gamma}$, the degrees of freedom are M+l and N+l.



As stated previously, Cl and C2 have historically been chosen such that

$$\int_{0}^{C1} h_{M,N}(x) dx = \int_{C2}^{\infty} h_{M,N}(x) dx = \frac{1-\gamma}{2}$$

This, of course, is the evenly split tails convention. It can be shown, however, that this method does not yield the optimal confidence interval.

The problem of finding the minimum length confidence interval is solved by applying a mathematical technique from the field of nonlinear programming. In essence, this nonlinear problem is

MINIMIZE:
$$\frac{s_y^2}{s_x^2}$$
 (C2 - C1)

Subject to:
$$\int_0^{C1} h_{M,N}(x) dx + \int_{C2}^{\infty} h_{M,N}(x) dx = 1 - \gamma$$

It is noted that the problem above is in reality a single variable line search. This becomes apparent when one chooses a value for C1, for then the value of C2 is fixed by the constraint. Thus, C1 is selected to serve as the independent decision variable. A single variable line search is then conducted over the interval $(0, H_{M,N}^{-1}(1-\gamma))$ where $H_{M,N}^{-1}(1-\gamma)$ is the inverse F distribution with M and N degrees of freedom. As C1 varies over this interval, C2 varies from $H_{M,N}^{-1}(\gamma)$ to infinity. By searching C1's interval, various pairs of (C1,C2) are obtained and used in



evaluating the derivative of the objective function. Where the derivative is zero, the objective function is minimized and the optimal values for Cl and C2 are then known.

When the criteria for optimality is changed from the ratio of variances to the ratio of standard deviations, the line search problem is the same as the ratio of variances except the objective function then has square roots in it. In other words, the problem is

MINIMIZE:
$$\sqrt{\frac{s_{y^2}}{s_{x^2}}} (\sqrt{C2 - \sqrt{C1}})$$
Subject to:
$$\int_0^{C1} h_{M,N}(x) dx + \int_{C2}^{\infty} h_{M,N}(x) dx = 1 - \gamma.$$

The logic and methodology in the above problem are the same as those in the ratio of variances and hence are omitted here.

A result of Scheffé [2] shows that reparameterizing with a logarithmic transformation and minimizing the length produces the shortest unbiased confidence interval for the ratio of two variances. The term "unbiased" as used here refers to Neyman's [1] notion of unbiasedness. Hence, in the context of this thesis, the unbiased nonlinear problem becomes

MINIMIZE: log [
$$\frac{C2}{C1}$$
]

Subject to:
$$\int_0^{Cl} h_{M,N}(x) dx + \int_{C2}^{\infty} h_{M,N}(x) dx = 1 - \gamma.$$



Again, as in the case of the minimum length confidence intervals for the ratio of two variances and the ratio of two standard deviations, the logic and methodology are the same, hence, again are omitted.

B. SUMMARY

This thesis contains the values necessary to construct the optimal confidence interval for the three parameterizations:

1) The ratio of two variances; 2) The ratio of two standard deviations and 3) The logarithm of the ratio of two variances. These values were obtained as solutions to the three nonlinear programming problems:

(1) MINIMIZE: C2 - C1

Subject to:
$$\int_0^{C1} h_{M,N}(x) dx + \int_{C2}^{\infty} h_{M,N}(x) dx = 1 - \gamma$$

(2) MINIMIZE: $\sqrt{C2 - \sqrt{C1}}$

Subject to:
$$\int_0^{C1} h_{M,N}(x) dx + \int_{C2}^{\infty} h_{M,N}(x) dx = 1 - \gamma$$

(3) MINIMIZE: $log [\frac{C2}{C1}]$

Subject to:
$$\int_0^{C1} h_{M,N}(x) dx + \int_{C2}^{\infty} h_{M,N}(x) dx = 1 - \gamma$$



As a final note, the statistic $\frac{s_y^2}{s_x^2}$ was dropped from the objective functions. This quantity is a random variable, and although its value influences the length in a multiplicative way, it can not be altered and has no role in the optimization process.



III. DISCUSSION OF ACCURACY

The precision of the tabled values is rather variable.

After much study, it was decided to print the values of Cl and C2 to six decimal places. This decision was reached only after all available information had been considered and evaluated carefully. The net result of this deliberating is an earnest belief that at least six significant digits are valid throughout. Since all values for Cl are less than one, and all values for C2 are greater than one, any inaccuracies of the printed values occur in C2. The supporting information follows.

The values in Appendix A were found from an optimizing algorithm which utilized four subroutines from the International Mathematical and Scientific Library. The routines were MDFDRE (the F probability distribution), MDFI (the inverse F probability distribution), MDBETI (the inverse incomplete beta distribution) and MDBETA (the incomplete beta probability distribution). These routines, as well as the optimizing algorithm, were programmed in double precision FORTRAN computer code which theoretically allowed for sixteen digit accuracy. These codes were executed on the IBM 360/67 computer located at the Naval Postgraduate School, Monterey, California.

The key to precise, accurate values from these programs was found in the incomplete beta probability distribution routine, for the other three routines called it for their primary values which they then transformed into the numbers they supplied to the optimizing algorithm. The incomplete beta probability



distribution routine was based upon Algorithm 179, the Incomplete Beta Ratio, of the Association for Computing Machinery. Tests which were independent of this thesis effort revealed that this algorithm had given accurate results to at least nine decimal places when compared to published values of the incomplete beta distribution.

Another check of the values supplied by the IMSL routines was conducted by first using the inverse F probability distribution program to find points which corresponded to a given probability. The F probability distribution program was then given these values in order to confirm the probabilities. Over 250 such tests were conducted with the known probabilities being reproduced accurately to eight decimal places. A wide range of points which were produced in this test were also fed into an independent F probability distribution program which was in the computer language of APL. These points again produced the known probabilities to within eight decimal place accuracy. By experimenting with these points, i.e., deleting the last digit from them and refeeding them into the APL program, results were obtained which implied that the points were good to at least six decimal places.

Finally, it was decided to check the values in Appendix A by comparing them to alternate solutions found from another optimizing algorithm. When a wide range of the published values of this thesis were compared to solutions found from the other algorithm which utilized the same routines, ten points out of



190 disagreed with each other and this occurred in the fifth decimal place of C2. These disagreements occurred repeatedly when the degrees of freedom were disproportionate, the first being much larger than the second (i.e., (9,1), (10,1), (25,1), (50,6), (60,7), etc.). Additional experimentation revealed that the discrepancies in C2 were caused by the nearly horizontal curve that the F cumulative distribution function assumed at high levels of probability. However, when the published values and their alternatives were tested in the independent, APL computer program of the F probability distribution, it was found that the published values satisfied the probability integral constraint better and gave a smaller confidence interval length.

In conclusion, for convenience of printing, it was decided to fix the values found in this thesis at six decimal places. This decision was not arrived at easily, but only after many hours of study, deliberation and computer usage. This decision was based upon the accuracy of the incomplete beta probability distribution subroutine, the demonstrated preciseness of the other subroutines and the high satisfaction of the probability constraint by the published values. Although discrepancies in C2 were found in about 5% of the cases checked, they occur only in the last two decimal places of eight or more digit numbers, and do not affect the probability statements or the length of the confidence interval in any noticeable way.



IV. CONCLUSIONS

A. OPTIMAL LENGTH CONFIDENCE INTERVALS

Minimum length confidence intervals offer a significant reduction in interval length over the classical intervals which are obtained by splitting the tails evenly. The amount of reduction obtained is a function of the degrees of freedom of the F probability distribution. Examination of the published values for the minimum length confidence intervals reveals that if M is fixed at 1 or 2, essentially all of the alpha level probability ($\alpha = 1 - \gamma$), has to be placed in the upper tail, thus giving confidence intervals with lengths that are two to six times smaller than the lengths of the split tail intervals. When the first degree of freedom is larger than 2, however, the reduction in length becomes more dependent upon the second degree of freedom, N. This principle is illustrated in Figures 2 and 3. Figure 2 shows that if N is fixed, the savings in interval length is a slowly decreasing function with a relatively limited range. Figure 3 shows that if N varies, then the reduction ratio is a sharply increasing function which ranges roughly from 1.1 to 2. It should also be pointed out that after both degrees of freedom become larger than 10, the lengths of the shortest confidence intervals are very close to the lengths of the traditional ones.

Another trend which is observed in the minimum length confidence intervals is the distribution of the tail area of the



appropriate F probability distribution. The general principle is that the upper (or right-hand) tail is always heavily favored with probability over the lower (or left-hand) tail. As is true of reduction in interval length, the distribution of tail area is dependent upon both degrees of freedom. When the first degree of freedom is fixed at 1 or 2, again almost all of the tail area has to go into the upper tail. When M is larger than 2, the tail area is redistributed as a function of N. In other words, with M larger than 2, the amount of probability in the lower tail increases as N increases. An example of this effect is shown in Figure 4. Again, after the degrees of freedom are simultaneously larger than 10 (although the upper tail is still favored heavily over the lower tail), the amount of length reduction is relatively small.

A close study of the published values for the confidence intervals of the ratio of two standard deviations reveals that the same principles noted in the discussion above also applies to them. Figures 5, 6 and 7 illustrate this fact. Because of this repetition, further discussion of these intervals is omitted.

The shortest unbiased confidence intervals do not offer a significant reduction in interval length when compared to either the equal tail intervals or the minimum length intervals. However, the unbiased intervals are unbiased; a claim which neither of the other two classes of intervals can make.

There are two general principles one should note about these shortest unbiased intervals. First, the reduction in the



logarithms of their length as compared to the classical ones depends upon the values of the degrees of freedom, M and N. If M is greater than N, the reduction ratio is always greater than 1. As the value of N approaches that of M, the reduction ratio approaches the value of 1. When M equals N, the shortest unbiased interval is the classical equal tails interval. This result is attributed to Scheffe [2]. When N is larger than M, the reduction ratio increases toward an upper limit of approximately 1.1.

Second, the distribution of tail area of the appropriate F distribution also depends upon the values of M and N. If M is greater than N, the upper tail is favored with more area. If M is less than N, the lower tail has more area. Of course, if M equals N, neither tail is favored over the other which implies equal tail area.

B. GENERAL

Three classes of confidence intervals for the ratio of two variances have been discussed in this thesis. The class that the practitioner chooses to use will depend upon his value judgments concerning the trade-off between interval length and biasedness. The minimum length confidence intervals are highly biased in favor of higher false values of the parameter. The unbiased confidence intervals have the shortest length for the logarithm of the ratio of the variances. However, when these confidence intervals are converted to the confidence intervals for the ratio of the variances, they have greater length than the minimum length



intervals. The equal tails intervals have greater length than the minimum length intervals and are biased (but slightly) in favor of higher false values of the parameter. Figure 1 illustrates the power functions which result from converting the classes of confidence intervals discussed into their equivalent tests of hypothesis. In conclusion, the practitioner must decide which of the two factors -- power or interval length -- is more important to him and use the appropriate tabled values.



APPENDIX A

The following tables are the principle objective and result of this thesis. Seven levels of confidence are addressed -.8, .9, .95, .975, .99, .995, .999 -- for the sets of degrees of freedom one through ten (by ones), twelve through twenty (by twos) and twenty-five through sixty (by fives). For each level of confidence, three tables appear; one for the minimum length confidence interval for the ratio of the variances, one for the minimum length confidence interval for the ratio of the standard deviations and a third for the shortest unbiased confidence interval.

Each table has five headings. "DF" means the degrees of freedom. The first number listed is the first degree of freedom (M) and is printed only at the beginning of each table. The second integer found is the second degree of freedom (N). N is printed for every row in the table. The columns labeled "C-1" and "C-2" contain the values which are solutions to the optimal length confidence interval problem. The column labeled "A-2/A-1" is the ratio of upper tail area to lower. The column labeled "Reduction" is the value of the ratio of the classical interval length to the shortest interval length. Minimum length confidence intervals are labeled as "coefficients" because in reality they must be multiplied by the test statistic, s_y^2/s_x^2 , to produce the true confidence interval length.



	100000000000000000000000000000000000000	667	1 	N 1628663446686704584086431 16286663446686704584086431 1628666665355 1628677777777666666666666666666666666666
0505050 34450	0.0	1.717188 1.706189 1.698010 1.691689 1.686657	* * * * *	664086 666556
5 5 60	0.0	1.682557 1.679152	* *	1.654 1.653

CONFIDENCE LEVEL=.8
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

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67-0	0.0	2.129928 2.043369	***********	1.576 1.542 1.547
100	0.0	1.934861 -898648	*	1.490 1.494
14	0.0	1 • 840 963 2 • 809 493 2 • 782 756	*	1 • 448 2 • 437
180 225	0.0	1.762319 1.746189 1.717643	*	• 429 • 422 • 430
30 35 40	0.0	1 • 698954 1 • 685768	* * *	1.403 1.397
450	0.0	1 • 668397 1 • 652374	* *	1.290 1.297
60	0.0	1.653392	*	1.383 1.384

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.3 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES



CONFIDENCE LEVEL= .8 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES





CONFIDENCE LEVEL=.8 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES



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DF 12 0.024359 14.940.5 3.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8 2.06.8
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CONFICENCE LEVEL=.8
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES



CONFICENCE LEVEL = .8
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES



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CONFIDENCE LEVEL = .8 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES



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DF 10 0.155 8 0 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165 9 0.165
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CONFIDENCE LEVEL = 8 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES



CONFIDENCE LEVEL = .8 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES



CONFIDENCE LEVEL = 8 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES





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250 350 360	0.0	2.917745 2.880695 2.854655	* * *	1 • 452 1 • 446 1 • 442
7455	0.0	2 • 820476 2 • 808658 2 • 799043	*	1 · 437 1 · 435
60	ŏ.c	2.791068	*	1.432

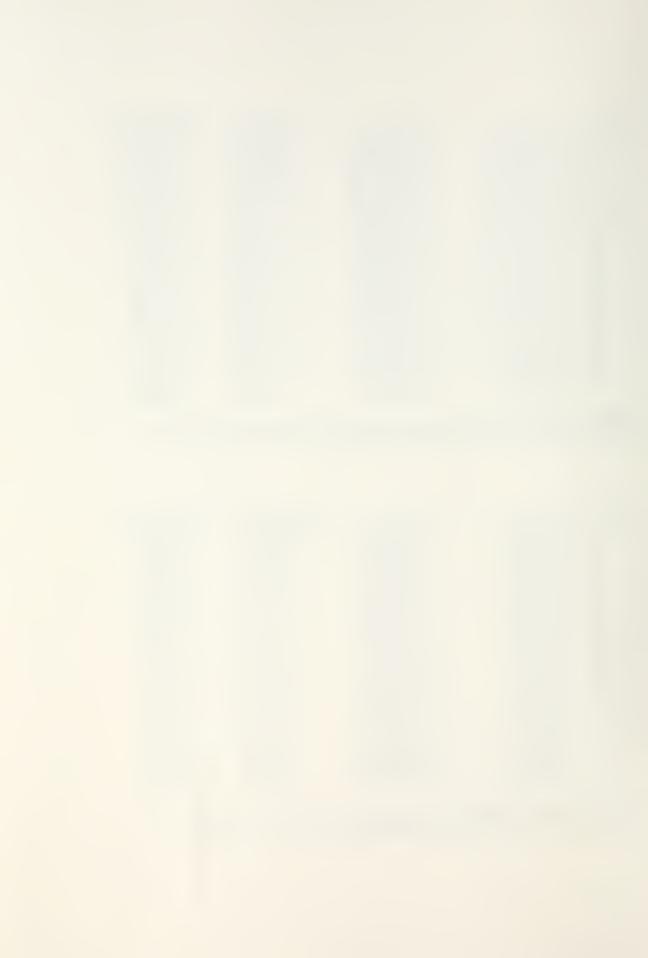
1234567890246805050505050 111112233344556	100000000000000000000000000000000000000	000356428266817456699515 0003573411569672379362535 -0002357341156474194506699515 -00043742110447419237935972 -0043742110447419237935972 -004374251004474192379359972 -0043742510447419237935999543742510444744193 -00435644156699515 -004357341564474450 -0043742515 -0043573415 -0043573415 -0043573415 -004357456681745 -0043745745 -0043745745 -0043745745 -0043745745 -0043745745 -00437456681745 -0043745745 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -004374 -	A-2/**********************	N 1959470869562559992730865 12039-73498654324-20005999 CO-755444435365736566669990009999 D421-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-
60	0.0	2.393255	*	1.295

^{*} EXCESSIVELY LARGE



^{*} EXCESSIVELY LARGE





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        OF
        C-1
        C-2
        A-2/A-1
        REDUCTION

        1
        0.004011
        58.907128
        100947.9
        4.017

        2
        0.018606
        9.354740
        1768.6
        2.050

        3
        0.034806
        5.277020
        380.8
        1.483

        4
        0.049582
        3.387718
        95.5
        1.483

        5
        0.062422
        3.387718
        95.5
        1.3332

        6
        0.073456
        3.037890
        49.3
        1.2261

        7
        0.082941
        2.811466
        49.3
        1.2261

        8
        0.091355
        2.553342
        39.7
        1.2261

        9
        0.104495
        2.447504
        28.9
        1.2231

        10
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        2.319654
        12.2.2
        1.1762

        12
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        2.3232640
        19.7
        1.152

        14
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        2.12917
        1.56
        1.162

        18
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        1.2.6
        1.129

        20
        0.149047
        2.018983
        1.0.6
        1.129
    </tr
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44556 44556	0.256865 0.261360 0.265037 0.268101 0.270693	1.826186 1.808451 1.794359 1.782892 1.773378	6.7 6.4 6.2 6.0 5.8	1.084 1.080 1.077 1.074 1.072









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DF C-1
30 1 0.030532 62.268766 32987.1 4.C15
2 0.080584 9.469779 844.5 2.041
3 0.126809 5.187336 197.6 1.635
4 0.166586 3.844127 87.3 1.464
5 0.200425 2.837099 34.8 1.258
6 0.229303 2.837099 34.8 1.258
7 0.254131 2.596488 26.0 1.258
8 0.275662 2.427280 20.7 1.226
9 0.2754691 2.301689 17.1 1.182
10 0.311087 2.06475 14.7 1.182
11 0.3318993 2.06475 14.7 1.152
14 0.361541 1.9674447 9.6 1.1322
14 0.361541 1.9674447 9.6 1.1322
14 0.361541 1.9674447 1.10053
18 841805 7.3 1.1164
16 0.3805763 1.841805 7.3 1.1104
25 0.409066 1.721484 4.8 1.0059
25 0.435069 1.633881 4.4 4.8 1.0059
25 0.468620 1.633881 4.4 4.4 1.0059
40 0.489394 1.556759 3.6 1.042
55 0.489394 1.556759 3.6 1.042
55 0.503550 1.5542130 3.4
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	100000000000000000000000000000000000000	91471885535083497862051 92649745530219749786205 683469346683499 641287711774708314683466461 1890769531164091547285311 18076953554444444444444444444444444444444444	A-2	N 1210215421449709#14905#185M21#1 1210215421449709#1665544M3121212017 1210215421449709#1665544M31212110111011011011011011011011011011011
105050 44556	00000	4.034746 4.056612 4.034310 4.016195 4.001191	* * *	وماسورخاساسور ۱۳۵۱ کاری ۱۳۵۱ کاری ۱۳۵۱ کاری افزاد امراز ۱۳۵۱ کاری ۱۳۵۱ کاری کاری ۱۳۵۱ کاری کاری کاری کاری کاری کاری کاری کاری

^{*} EXCESS IVELY LARGE



^{*} EXCESSIVELY LARGE



^{*} EXCESSIVELY LARGE









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DF 1 0.013421 246.465937 245097.0 4.004
2 0.042812 19.440474 496.8 1.6222
4 0.097556 5.861737 191.1 1.451
5 0.119822 4.6625686 166.1 1.258
6 0.139042 3.947889 66.1 1.2578
8 0.155699 3.523164 47.5 1.2223
9 0.182974 3.022759 29.7 1.1844
10 0.194242 2.863385 24.9 1.1578
10 0.194242 2.863385 24.9 1.1578
11 0.213228 2.638026 19.0 1.1578
12 0.2213228 2.638026 19.0 1.1578
14 0.2241242 2.863385 24.9 1.1538
16 0.2241242 2.863588 15.5 1.1238
16 0.2241242 2.8638026 19.0 1.1578
18 0.2251855 2.486358 15.5 1.1233
18 0.251855 2.495031 6.8 6.8 1.00877
20 0.2608438 2.918604 8.6 6.8 1.00877
20 0.308502 1.9957363 6.8 1.0070
25 0.314684 1.905321 5.6 6.3 1.0065
25 0.314684 1.905321 5.4 1.0555
60 0.323913 1.8871049 5.2
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DF 1 0.017044 248.0153333 22.06501.5 2.0629 1.00024 2.065564 19.45358 467.5 11.655664 19.4535664 19.4535664 19.4535664 11.225544 19.45356 60.1137.9767 3.478.298.5 22.06501.5 2.2254 12.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20601.5 2.20
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DF 1 0.020379 249.33 2065.22889 249.33 20.0581488 8.6487976 12.6495.53 22.8899.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22889.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899.33 26.22899
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DF C-1

1 0.028267
2 0.074371
3 0.117799
4 0.155927
5 0.188979
6 0.217677
7 0.242741
8 0.21476818
9 6 0 0.217677
7 0.242741
8 0.264788
9 0.284320
9 0.284320
9 0.284320
10 0.301741
12 0.331492
12 0.4415187
14 0.3776512
12 0.488989
10 0.3939993
20 0.4090709
11 8193006
12 0.4090709
11 8193006
12 0.478983
11 0.478983
12 0.478983
13 0.478983
14 0.478983
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17 10 184
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18 0.5522228
18 0.629669
18 0.6377
18 0.6377
18 0.6377
18 0.6377
18 0.6377
18 0.6443
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OF 1 0.029742 252.198426 187968.9 4.0004 2.021 130N 2.0077318 19.487615 23339.2 1.021 14477 2 1.0122031 8.586503 424.4 1.0124 1.0122031 8.586503 424.4 1.0122031 8.586503 424.4 1.0122031 8.586503 424.4 1.0122031 8.586503 424.4 1.01220 1.0250 8.7.7 1.3533 1.0250 8.7.7 1.3533 1.0250 8.7.7 1.3533 1.0250 8.7.7 1.3533 1.0250 8.0224929 3.0328746 2.0661 2.215 9.0.273586 3.0328746 2.0661 2.215 9.0.293784 2.0.2508483 2.0.5 1.0124 1.00.311839 2.0.258483 2.0.5 1.0124 1.00.311839 2.0.424422 1.5.4 1.126 1.126 1.00.342709 2.0424422 1.5.4 1.126 1.126 1.00.342709 2.0424422 1.5.4 1.126 1.00.342709 2.061753 8.1 1.00.399 1.00.4978387 2.061753 8.1 1.00.999 1.00.4978387 2.061753 8.1 1.00.999 1.00.613 1.00.999 1.00.4788000 1.0867929 1.00.613 1.00.999 1.00.613 1.00.999 1.00.613 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.00.999 1.0
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10000000000000000000000000000000000000	193332192389972465074391 034468068826325963235271 29637763168877703597743789235271 -800477035975014358927427005 075420880777081977864827413 0805295219868827413 08052952198654437332 08052952198654437332 080529521986555555555555555555555555555555555555	A-1 /************************************	N 13974178821,424834848479765 13974178821,424838756655555 COC654443711373737222222222222222222222222222
40 0.0 45 0.0 50 0.0 55 0.0	5.423937 5.37233 5.316379	* * * * * *	1.2619 222555 1

DF 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		N 10149, 364215, 3422150040642109 10149, 366543, 3621, 300009 10149, 366543, 3621, 300009 10149, 366543, 3665443, 3665443, 3665443, 3665443, 3665443, 3665443, 3665443, 3665443, 3665443, 36654444, 36654444, 36654444, 36654444, 366544444, 366544444, 3665444444, 366544444444444444444444444444444444444
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^{*} EXCESSIVELY LARGE



^{*} EXCESSIVELY LARGE



F 1217456789004680505050505050505	5888336003888050829744300000000000000000000000000000000000	487652099278534304459937 04078203861116002180309217 04013044555846902180309324 11330822660920446455443868 C11372981630755321488177666 19496554444333333322222222	1 001811155242614420300 A 245721388213314905A0876 /* 2233175842976544783222 2 1143632111	N I p. 157 46 2477 p. 17 p. 30 9 210 0 40 64 p. 30 T 0 p. 156 p. 17 42 p. 487 5 4 40 12 p. 15 p. 30 00 0 C C O O 6 43 3 2 2 2 2 2 p. 15
60	0.059847	2.648224	25.2	1.099

^{*} EXCESSIVELY LARGE



DF 8 1 2	C-1 0.0 0.008997 0.018548	C-2 956 • 6562 21 39 • 375352	A-2/A-1 * 17168.2	REDUCTION 4.001 2.013
3456	0.027818 0.036209 0.043642	14.544/75 8.986995 6.766395 5.611400	2097 • 7 675 • 65 198 • 4	
2 8 10	0.050189 0.055960 0.061063 0.065596	4.912930 4.448446 4.118552 3.872737	102.1 81.0 867.	461001 001 001 001 001 001 001 001 001
14680	0.073273 G.C79505 0.084653 0.088970	3 • 531 (31 3 • 306944 3 • 147875 3 • 029489	00.149 449.	10000000000000000000000000000000000000
223350	0.092640 0.099777 0.104953 0.108873 0.111944	1255555000627145997016417 2577990345333478997016417 26546612883277984927121345 0635976914187304238709090909090909090909090909090909090909	22.0 19.2 17.4	1 • 102 1 • 102 1 • 1091
1274567890246805050505050 17177223744556	0.114414 0.116443 0.118140 0.119579	2 • 520154 2 • 489381 2 • 464477 2 • 443909	27654510CCC11980214121995 •••••••••••• 871788621170C49529765486 1097293C865432222111111111111111111111111111111111	

^{*} EXCESSIVELY LARGE



^{*} EXCESSIVELY LARGE













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OF C-1
55 1 0.023593 1009.036684 1046024.1 4.0011
2 0.023593 1009.485067 8889.2 10.60388
4 0.1020311
4 0.136331 86.159876 1488.7 12.245
6 0.1668868 4.990501 90.0 11.2245
8 0.236872 3.82121205 455.7 11.2191
8 0.2355343 3.82111 3.9912 11.1144
10 0.2719324 2.888111 29912 11.1144
11 0.3246872 3.82121 205 11.1249
12 0.3304505 12.289925 11.1249
13 0.3246872 12.891292 11.1249
14 0.336667373 12.891292 11.1249
14 0.336667373 12.891292 11.1249
15 0.344419 12.891292 11.1249
16 0.3444419 12.891292 11.1249
17 0.429473 12.9988 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.993845 12.9938
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DF 1 2 3 4 5 6 7	C-1 0 • 0 0 • 0 0 • 0 0 • 0	C-2 4052.1802522 4058.502522 21.197690 16.2581023 11.2581023 11.2581023	A-2/A-1 ** * * * * * * * * * * * * * * * * *	REDUCTION 40.01588146665111.320
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	100000000000000000000000000000000000000	93207334192350886708776 912077334192350886770 20267282391962597708770 202678563642205949743067770 1512544564363859294483797 2026321000988888777777777777777777777777777777	* * *	058876659708038040755750000804075575000000000000000000
344556	0 · 0 0 · 0 0 · 0 0 · 0 0 · 0	7.419117 7.314100 7.233868 7.170577 7.119377 7.077106	* * * * * *	

CONFIDENCE LEVEL=.99 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

47345678904468150505050 6 0 0		0100000477817288455276188192 0005203467817288455276000500374617330845527682999344018199 00060097724642196823039944081119 000600977246421968229993999906296600595201115992 0006009726600000000000000000000000000000		NOO609 = 1969 6969 594484 C8653 TO = 19667 397-5461409993777-66666 COC643 MANAGENERAL OBSTANT AND
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^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.99 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

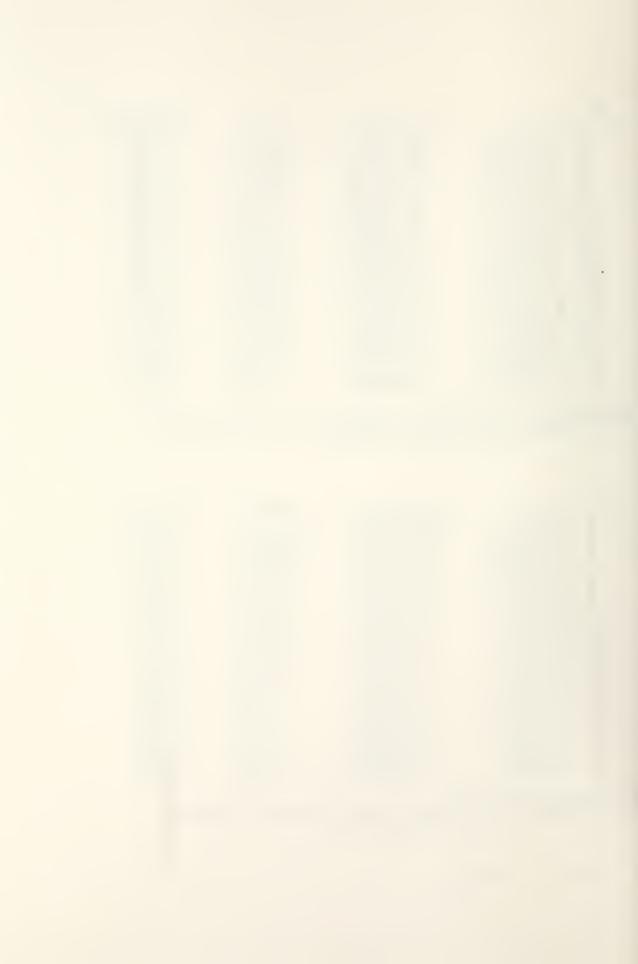
^{*} EXCESSIVELY LARGE



CONFICENCE LEVEL = .99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

12345678902468050505050 F D D 6	94422533995361119005871 1146285333722262595979 000000000000000000000000000000000	5305344990651273529969 197760908417583728539 18317760908417583728539 183107495557174483307218539 183107665577173930749 183107665577173930749 18975088769249 18975088769307444 18975088769307444 189750887655444433333333333333333333333333333333	7 718154099507896383056 A 8026123826592022513853 /* 722761324841097655444 2 3937964321311 A 61	N 1064C2825507,4900,407,607 1064C382550764432,40009 10645963,40764432,40009 10645,963,40764,40764,40764,40764 1075,40764,40764,40764,40764,40764 1075,40764,40764,40764,40764,40764
45 55 60	0.035197 0.035971 0.036621 0.037174	3.244436 3.198659 3.161726 3.131303	48.0 45.5 43.6 42.0	1.00 1.097 1.095

^{*} EXCESSIVELY LARGE



CONFICENCE LEVEL=.99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=. 99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

10010000000000000000000000000000000000	5318194441207228656 9518665941120722865610975566493175428659486264931754286594862694365664493112072286564936564936566493665666666666666666666	570129689261099401808792461229416374273199400961769274458099716980877692745868327643855129339617737659746554433333333222222	1 5946957632492254,4654 A 5268271872894030865435 *2723094086433322713227425594	N 1051344802049299978217 100034852085421149887 C00448142214114914140060 U••••••••••••••••••••••••••••••••••
)344550 0	0.120436 0.120436 0.123271 0.125608 0.127567 0.12923	2.901668 2.827110 2.770378 2.725767 2.589769 2.660113	1464694 1865489 1965489	1.082 1.077 1.073 1.068

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = 99 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

F-12m45.078900446805050505050 D-14 14	1 04669831651050447533399000000000000000000000000000000000	27794304427199410616072 988700150944499940616072 9887001509444999 9730962015094349514995199439 1773097215050897599488 068508994994994994994994994994994994994994994	1 88605560254963474535940 A 8422143935484464230999 /* 03892440764322241111 2 51883211 A 3	N 10502-145647-1300278-162964 10502-145647-1300277662555 1050484-1597532-1000000000000000000000000000000000000
45050 5050	0.193299 0.196938 0.199995 0.202598	2.539216 2.539216 2.458557 2.428852	1509.4 109.4 199.4	1.062 1.059 1.056

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL= .99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

#23456780004468050505050 F D 8 8 1	52828425884355722144997 5282842588435722144997 574406502308684166019187 66526911368898623295093 - 24689023456788623295093 - 000000000000000000000000000000000000	05332989505737787369702 1265888474366977090469702 726182309327742228989555 7261823093217742228989555 -214582623773835128335985177 -21458262377383512833598373 05476542484953110833598373 19964497654433333332222222	1. 3.163045020058 - 1.48446 - 1.73 A 83034607559040 - 1.4098877 /*1.774529653322 - 1.4773 - 1.4929653322	N 1059-00:104-148965722:1506208 10093484-19742:10987655534 100948122:2-19742:1-1-10987655534 100942-1-1012:1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1
405 450 550 60	0.245304 0.250019 0.253989 0.257377	2.398869 2.353907 2.317570 2.287592	8 • 6 8 • 1 7 • 7 7 • 3	1.052 0.050 1.068

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = .99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

-12014567890044680505050505 F D D D D S	30834939003534857346 952623252523123209164443 66929252312325287379315658 6692924679024678134567 667924678134567 667924678134567 667924678134567	4984401869050904750857 9906447769050904750857 2744906447707573337309104 2674962613330807332421696272330882831232422169902 054473196263097532422126838 0975554483832222222222222222222222222222222	1 55771877734475851119040 A 05945768624964197764 2 736211 A 22	27 104900000000000000000000000000000000000
45050 45050	0.3565884 0.365882 0.373682 0.380305 0.385997	2.189118 2.130005 2.083247 2.045320 2.013927	76.63 76.63	1.005 0045 0049 0037

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = \$9 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = .99
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

-12:045.67:850246805050505050505050505050505050505050505	100000000000000000000000000000000000000	0008106724972045991647111 9002281343947966923698423149 2900943443246696913884684764161349 -90981346040202111889588670413149 07235404020211188958867049 04072354011988777766666655555 999421111111	7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	N 10556333-8807-96704594-897444 10556333-8807-96704594-8974444 106441334420204-8-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-
60 60	0.0	5 • 843 <u>1</u> 4 <u>1</u> 5 • 7949 9 <u>1</u>	*	1.145

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = 995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = . 995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



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23
144.0.899.036.92.899.036.92.899.036.999.036.99.036.99.036.92.07.92.2
231.440.899.036.92.899.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.99.036.9
7<sup>DF</sup>
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- 453521164321111

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0.0012615940
0.01261594140
0.012613920
0.0127920729
0.0224301052815335
0.02247020
0.023126815335
0.0335899324424419
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CONFIDENCE LEVEL COEFFICIENTS FOR FOR THE RATIO =• 995 MINIMUM LENGTH CONFIDENCE INTERVAL OF TWO VARIANCES

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7938834591292494752410
- 827587C43422C17C52C876
- 7631
- 7631
                                                                                                                       27898674815173746938579
26574609280346139946855324
2657450421447272944152591
265780025638039669385
265780025638039669385
265780025638039669385
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                                                                                          239
1
8
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CONFICENCE LEVEL= COEFFICIENTS FOR FOR THE RATIO O =.995 MINIMUM LENGTH OF TWO VARIANCES CONFIDENCE INTERVAL

EXCESSIVELY LARGE



CONFIDENCE LEVEL=.995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



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NCE LEVEL=.995 IENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL HE RATIO OF TWO VARIANCES CONFIDE COEFFIC FOR T

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CONFIDENCE LEVEL = • COEFFICIENTS FOR M
FOR THE RATIO OF 995 INIMUM LENGTH TWO VARIANCES CONFIDENCE INTERVAL

EXCESSIVELY LARGE



CONFIDENCE LEVEL= .995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

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4505 505 60	0.215869 0.220242 0.223929 0.227030		10.3	1. C59 1. C555 1. C47

^{*} EXCESSIVELY LARGE



CONFICENCE LEVEL=.995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

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^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = .995 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

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223344556	0.409150	2. 967.2190 2. 967.918 2. 464.87 2. 461.3764 2. 161.3764 2. 105.90 2. 105.90 2. 105.90	-67.8544722781 19.621987661541	11-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1

^{*} EXCESSIVELY LARGE



^{*} EXCESSIVELY LARGE



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40 0.0	12.896335	*	1.141
45 0.0 50 0.0	12.392170	*] •]36
55 55 60 0.0	12.085346	*	1.133
60 0.0	11.972987	*	1.132

CONFIDENCE LEVEL = . 999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

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^{*} EXCESSIVELY LARGE



CONFICENCE LEVEL = .999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = 999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESS IVELY LARGE



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ONFIDENCE LEVEL = •
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FOR THE RATIO OF 999 INIMUM TWO V HM LENGTH CONFIDENCE VARIANCES INTERVAL

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CONFIDENC COEFFICIE FOR THE E LEVELS NTS FOR RATIO O =-999 MINIMUM LENGTH OF TWO VARIANCES CONFIDENCE INTERVAL

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.999
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

	3943149138672762 0.016520044423978677762 0.02344423997107762 0.0234442399710774877 0.0234442399710774877762 0.02344423997107762 0.0234442397762 0.0234442397762 0.0234442397762 0.0234442397762 0.0234442397762 0.023444777762 0.023447777762 0.0234477777777777777777777777777777777777	275257 959176978306735 9786357 959176978306735 978608855490881748827965465549088174481720653 29966945129088174886987 299766945330946572886987 29976673098655444333333	33352153244 12913564676 1 22419148410978184199 A 3377766592965432221 2*3300953211 2 3362 A 33	0009227308642~098768535 C009227308642~098766555 C004432224~1249000000000000000000000000000000000000
45 50 55 60	0.117971 0.120568 0.122759 0.124631	3.378453 3.292335 3.223401 3.166983	21.6 19.7 18.2 17.0	1.058 055 1.051

^{*} EXCESSIVELY LARGE



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CONFID COEFFI FOR ENCE L CIENTS THE RA EVEL FOR TIJ 999 INIMUM LENGTH TWO VARIANCES = = . M OF CONFIDENCE INTERVAL

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- $7774466971255872865322

- $9186742211

- 24641

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CONF COEF FO ENCE LEVEL CIENTS FOR THE RATIO ID FI R =. 999
MINIMUM LENGTH
OF TWO VARIANCES CONFIDENCE INTERVAL

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL=.999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = . 999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = .999
COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL
FOR THE RATIO OF TWO VARIANCES

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^{*} EXCESSIVELY LARGE



CONFICENCE LEVEL= .999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

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450 550 60	0.344820 0.354073 0.362031 0.368952	2.517128 2.431794 2.363147 2.306704	8.9 8.0 7.4 6.9	15 138 6 04438 6 0033 1 0 033 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

^{*} EXCESSIVELY LARGE



CONFIDENCE LEVEL = .999 COEFFICIENTS FOR MINIMUM LENGTH CONFIDENCE INTERVAL FOR THE RATIO OF TWO VARIANCES

* EXCESSIVELY LARGE



	09.4500003285486986083 70265675-2553597592577 700627224907141597592577 00002172469071441997592577 00000000000000000000000000000000000	83597-1-166709654813340491444882304040437709-8570425 4446450786487709-9570625 254-154365098642949-9599999999999999999999999999999999	144675136067196437108876665 A	N 100014216029440010-186297454444 1-460466-16987766555444444 1-460466-169877665556444444 1-46046-1698776665556444444 1-46046-16987766-169876-1
705050	0.043678 0.044173 0.044572 0.044902 0.045178	100 100 100 100 100 100 100 100 100 100	176665 176865	1.00444 1.00443 1.0043

^{*} EXCESSIVELY LARGE



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9205771448511770588882
92053183711793168886
92053183715758158154588677777777
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0980041791518375842405298
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CONFIDENCE LEVEL=.995 SHORTEST UNBIASED CONFIDENCE INTERVAL



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APPENDIX B

ILLUSTRATIONS

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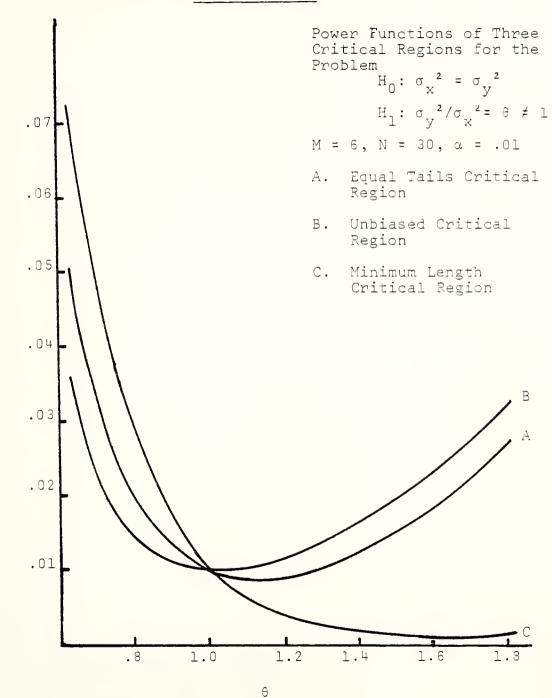
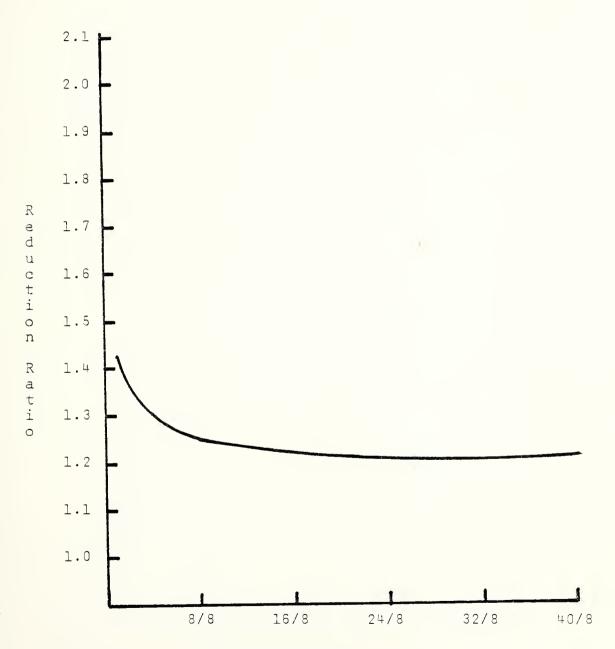


Figure 1



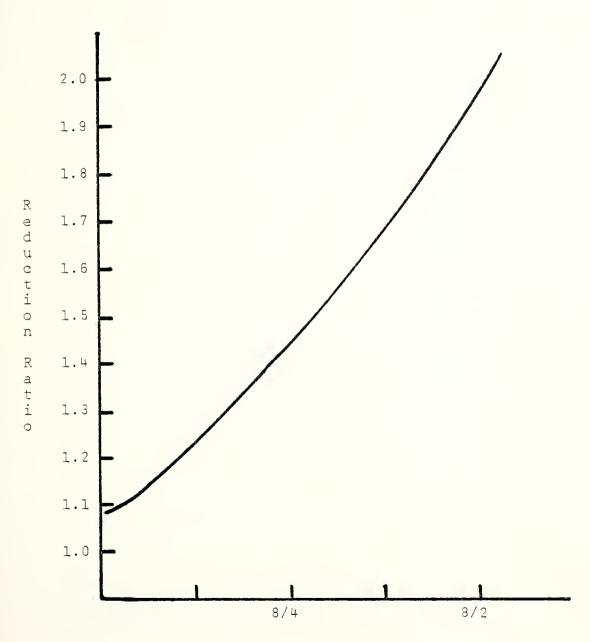
Reduction Ratio Resulting from Use of Minimum Length Interval for the Ratio of Variances in Lieu of Equal Tail Interval



Ratio of Degrees of Freedom (M/N); N Fixed at 8; α = .05 Figure 2

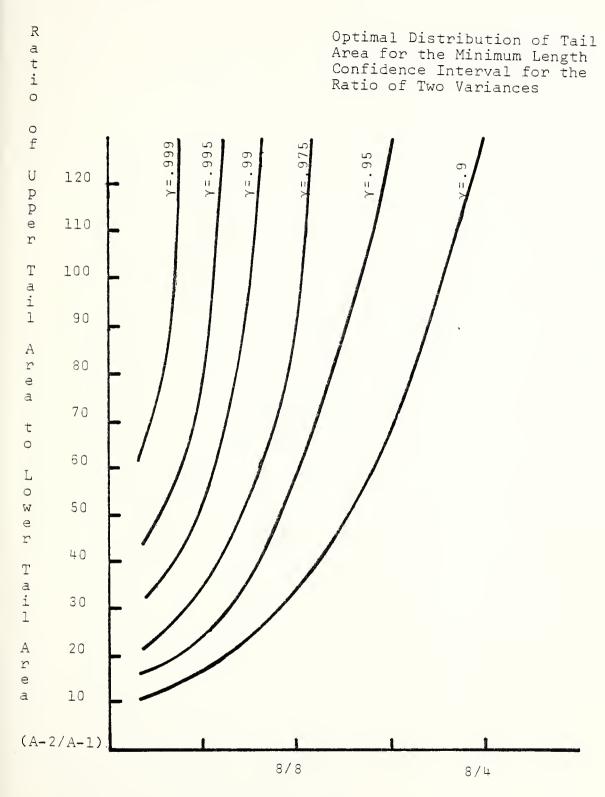


Reduction Ratio Resulting from Use of Minimum Length Interval for the Ratio of Variances in Lieu of Equal Tail Interval



Ratio of Degrees of Freedom (M/N); M Fixed at 8; α = .05 Figure 3





Ratio of Degrees of Freedom (M/N); M Fixed at 8 Figure 4



Reduction Ratio Resulting from Use of Minimum Length Interval for the Ratio of Standard Deviations in Lieu of Equal Tail Interval

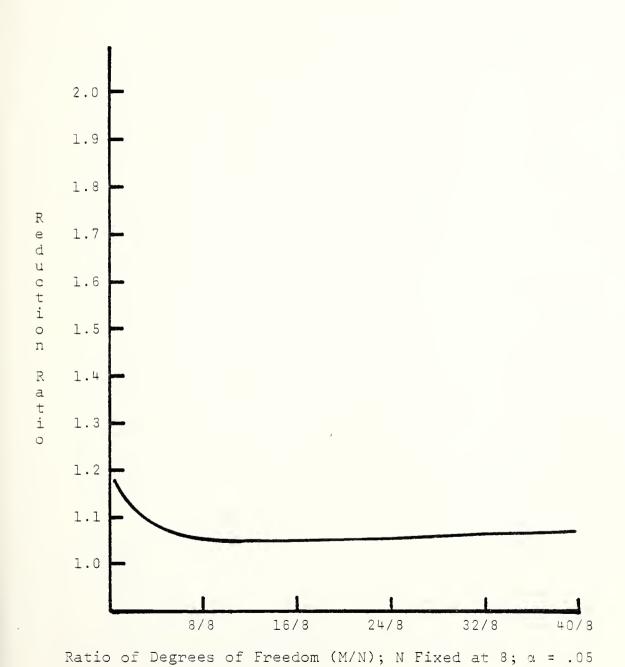
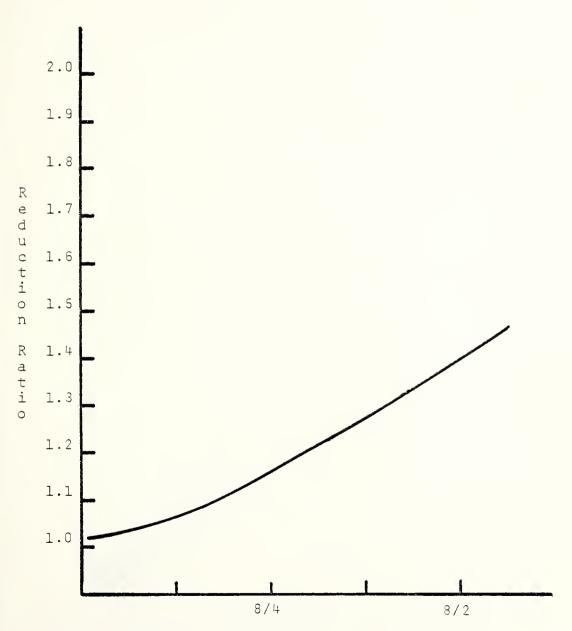


Figure 5



Reduction Ratio Resulting from Use of Minimum Length Interval for Ratio of Standard Deviations in Lieu of Equal Tails

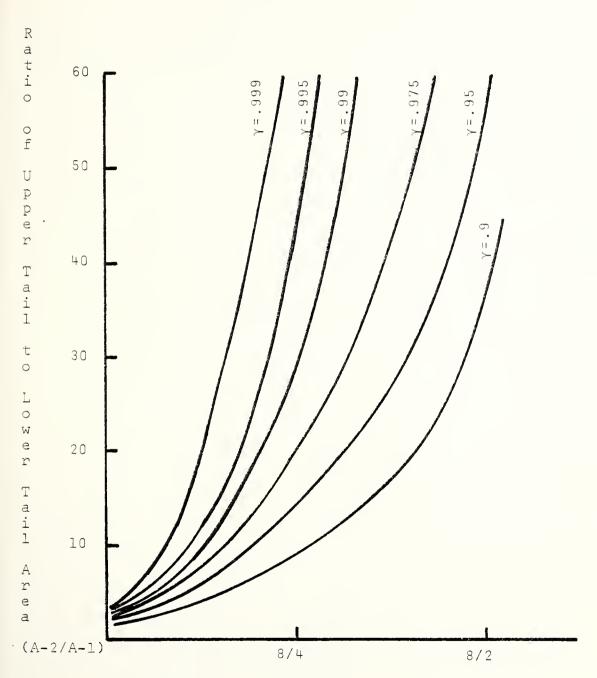


Ratio of Degrees of Freedom (M/N); M Fixed at 8; α = .05

Figure 6



Optimal Distribution of Tail Area for the Ratio of Two Standard Deviations



Ratio of Degrees of Freedom (M/N); M Fixed at 8

Figure 7



APPENDIX C

MATHEMATICAL DERIVATIONS

This thesis solved three parameterizations of the same nonlinear programming problem. They were

(1)
$$\phi_1 = C2 - C1$$

Subject to:
$$\int_{C1}^{C2} h_{M,N}(x) dx = \gamma$$

(2)
$$\phi_2 = \sqrt{C2 - \sqrt{C1}}$$

Subject to:
$$\int_{C_1}^{C_2} h_{M,N}(x) dx = \gamma$$

(3)
$$\phi_3 = \log \left[\frac{C2}{C1} \right]$$

Subject to:
$$\int_{C1}^{C2} h_{M,N}(x) dx = \gamma$$

After some study, it was found that each of these problems was unimodal and continuous over the range of a single, arbitrary decision variable, Cl. Because of these properties, the problems could have been solved by either the golden section search scheme or the bisection search method. The published values in Appendix A were obtained as solutions from the bisection search method.



The bisection procedure used was as follows. An interval of the decision variable was suspected of containing the optimal value. In this thesis, the suspected interval was always $(0, H_{M,N}^{-1}(1-\gamma))$. The interval being searched was then split in half (bisected), and the sign of the derivative for the objective function was evaluated there. The derivatives of the three objective functions with respect to the decision variable C1 were:

$$(1) \frac{d\phi_1}{dC1} = \frac{\partial \phi_1}{\partial C2} \cdot \frac{dC2}{dC1} + \frac{\partial \phi_1}{\partial C1} \cdot \frac{dC1}{dC1}$$

$$= \frac{dC2}{dC1} - 1$$

$$(2) \frac{d\phi_2}{dC1} = \frac{\partial \phi_2}{\partial C2} \cdot \frac{dC2}{dC1} + \frac{\partial \phi_2}{\partial C1} \cdot \frac{dC1}{dC1}$$

$$= \frac{1}{2} (C2)^{-\frac{1}{2}} \cdot \frac{dC2}{dC1} - \frac{1}{2} (C1)^{-\frac{1}{2}} \cdot 1$$

$$(3) \frac{d\phi_3}{dC1} = \frac{\partial \phi_3}{\partial C2} \cdot \frac{dC2}{dC1} + \frac{\partial \phi_3}{\partial C1} \cdot \frac{dC1}{dC1}$$

$$= \frac{1}{C2} \cdot \frac{dC2}{dC1} - \frac{1}{C1} \cdot 1$$

Since $\frac{dCl}{dCl}$ is the identity, the only remaining unknown in the derivations is $\frac{dC2}{dCl}$. This was then found by applying Leibniz' Rule and the Implicit Function Theorem to the constraint equation. The result was:



$$\int_{C1}^{C2} h_{M,N}(x) dx = \int_{C1}^{C2} \frac{\frac{M}{2}}{[N+M \cdot x]^{\frac{M+N}{2}}} dx = \gamma$$

and
$$\frac{dC2}{dC1} = \left[\begin{array}{c} \frac{C1}{C2} \end{array}\right]^{\frac{M}{2}-1} \cdot \left[\begin{array}{c} \frac{N+M\cdot C2}{N+M\cdot C1} \end{array}\right]^{\frac{M+N}{2}}$$

If, upon evaluation, the value of the appropriate derivative was positive, then the midpoint was chosen as the new upper bound on the search interval. Of course, if it was negative, this point became the lower bound on the search interval. This process was continued until the length of the search interval was less than a prescribed tolerance factor. For this thesis, this factor was 10^{-3} . Once the length of the search interval was less than this, the midpoint of the interval remaining was selected as the solution to Cl. Once the optimal value of Cl was fixed, the probability in the lower tail (i.e., the area under the F density curve between 0 and Cl) was determined. Subtracting this probability from 1- γ yielded the probability in the upper tail. Substituting this value into $H_{N,M}^{-1}$ gave $\frac{1}{C2}$ which, when inverted, resulted in the published value for C2.



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